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MELVILLE T. COOK, Editor.

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(SECOND PAPER)

By MELVILLE T. COOK

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THE EGGPLANT BLIGHT AND FRUIT ROT IN PORTO RICO

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The two major diseases of the eggplant in Porto Rico are the bacterial wilt and the Phomopsis blight. They are probably of about the same seriousness on this Island. Eggplant growing is probably on the increase. The Phomopsis disease is spreading over the various sections where the host plant is grown. Studies have been carried out with this malady during the last three years. It is the scope of this paper to present our knowledge of the disease up to the present time.

PLANTS AFFECTED

The eggplant (*Solanum melongena* L.) appears to be the only known host of *Phomopsis vexans* (Sacc. & Cyd.) Harter.

VARIETAL SUSCEPTIBILITY

The information in the literature is rather insufficient on the question of susceptibility of eggplant varieties to the Phomopsis blight. Halsted (**9**) in discussing experiments on the control of the disease lists four varieties, namely, Early Long Purple, New York Improved, Improved New York Spineless and Black Pekin. He does not cover the question of the relative susceptibility of those varieties. Figures are given in that paper on sprayed and non-sprayed plots, but they cannot be used in figuring the percentages of diseased fruit because of the small numbers. Bruner (**1**) reports the Florida High Bush and the Excelsior as showing considerable resistance to the Phomopsis blight in Cuba. He almost gives the former as the more resistant of the two. Stevenson and Rose (**24**) reported 43 per cent of dead or dying fruit in a count of 322 plants in Porto Rico. Although they mention in the report that the Improved Purple Thornless and the Florida High Bush were planted, they fail to state whether all the count was from only one or from both varieties. If both were included then the number of plants of each variety is wanting. Ed-

gerton and Moreland (**4**), however, found the Florida High Bush a very resistant variety as compared to the Black Beauty and the Mammoth Purple. Under conditions in which the latter two types fail the Florida High Bush "results in greater yields and a longer picking season". More recently Weber (**26**) has reported the native wild eggplant of Florida as immune and further states that selections from crosses between the commercial and the wild plants exhibited resistant qualities.

The disease having been found quite widespred in 1926, tests were conducted in 1927 and 1928 to determine the degree of susceptibility of some of the eggplant varieties in Porto Rico. The following commercial varieties were used in these tests: Black Beauty, New York Spineless, Excelsior, Florida High Bush, New Orleans Market, Large Round Purple. Some Porto Rican varieties not suitable for export were also planted in the experiment: "Fajardo", a plant bearing long, green gourdlike fruits. This is a very vigorous and prolific plant. The "Pompadour", a strong plant with long-ovate fruits of a white color with purple stripes. The "University", a plant bearing round pink fruits. The "Camuy", a prolific plant bearing small, cylindrical, light purple fruits. A plant with round green fruits was discovered in a population of New York Spineless plants and propagated. It has been tentatively referred to as *"Green"*. All the varieties given above were planted in rows of 80 plants each, three rows of each variety. Observations of the preceedings season showed the land to be infested with the pathogen. The results appear in Table I.

TABLE I

SHOWS RELATIVE AMOUNT OF THE DISEASE ON DIFFERENT VARIETIES

Row	Variety	Plants		
		Sound	Diseased	Per cent Diseased
1, 12, 23	Black Beauty	90	150	62.50
2, 13, 24	New York Spineless	84	156	65.00
3, 14, 25	Excelsior	71	169	70.42
4, 15, 26	Florida High Bush	93	147	61.25
5, 16, 27	New Orleans Market	73	167	69.58
6, 17, 28	Large Round Purple	91	149	62.08
7, 18, 29	"Fajardo"	102	138	57.50
8, 19, 30	"Camuy"	94	146	60.83
9, 20, 31	"University"	70	170	70.83
10, 21, 32	"Pompadour"	128	112	46.66
11, 22, 33	"Green"	63	177	75.41
	Total all varieties	959	1,681	63.67

It was thought at first that counts of diseased and non-infected fruit would be of interest. It was soon found that such counts would not allow of a fair comparison for the reason that a large number of the infected plants died before any fruits were formed. Hence, in recording the number of fruits a large item would naturally be overlooked, which if it were not for the premature death of the plants would appear as diseased fruits. The only other means of estimating the percentage of infection in the various rows was by counts of the plants which bore fruit with disease spots or which had large cankers on the stems, those that had been girdled near the surface of the soil and were eventually killed and even those completely blighted before the production of blossoms. All these were included under "diseased." The plants considered as sound were those which bore only sound fruits and did not show any cankers on the stems or petioles, whether they had any small spots on the leaves or not. It must be observed that a large number of these "sound" plants had one or several leaves with small Phomopsis spots. This arbitrary classification was made because it is known that plants with these symptoms usually bear normal sound fruit.

An examination of the table shows that infection varies from 46.66 per cent for the variety named "Pompadour" to 75.41 per cent for that listed as *"Green"*. Out of the eleven varieties nine showed more than 60 per cent diseased individuals. The differences among these nine varieties do not appear to be sufficient to class any of them as more resistant than the other. The difference between "Pompadour"—46.66 per cent infection and "Camuy"—60.83 per cent—, for instance, would appear to be significant and one might be tempted to regard the former as more resistant than the latter. In the writer's opinion, in this particular disease, the number of diseased plants fluctuates so much even within one variety that those differences should not be given much weight. To throw more light on this point figures are presented in Table II of diseased and healthy plants in a planting of the Black Beauty variety. Notes were taken in Cayey, Porto Rico, during the month of December, 1927. The plants were bearing and the same system was followed in the classification of the healthy and diseased plants as was observed in Table I.

TABLE II

Row	Plants			
	Sound	Diseased	Total	Percentage diseased
1	23	48	71	67.61
2	29	42	71	59.15
3	27	50	77	64.94
4	36	42	78	53.85
5	41	42	83	50.60
6	37	42	79	53.16
7	37	45	82	54.88
8	38	37	75	49.33
9	43	52	95	54.74
10	43	48	91	52.75
11	41	38	79	48.10
12	53	35	88	39.77
13	51	45	96	46.88
14	48	40	88	45.45
15	53	57	110	51.82
16	41	45	86	52.33
17	38	42	80	52.50
18	59	34	93	36.56
19	47	47	94	50.00
20	59	41	100	41.00
21	53	43	96	44.79
22	60	36	96	37.50
23	49	48	97	49.48
24	42	57	99	57.58
25	50	46	96	47.92
Totals	1,098	1,102	2,200	50.01

A glance at the table will show that there are all kinds of variations in the percentage of diseased plants in the different rows. The lowest figure was 36.56 per cent in row No. 18; and rows No. 22 and No. 12 showed 37.50 per cent and 39.77 per cent of diseased plants respectively. On the other hand in rows No. 1 and No. 3 the diseased plants made 67.61 per cent and 64.94 per cent of the population respectively. The deviations from the average for the variety in this case are worthy of examination.

Should we attach much weight to those differences occurring within the same variety, in the same fields, all plants the same age, etc.? If we do not, and that would be the logical consequence, then should we establish any difference between this case and that of a field where many varieties are grown? In our opinion we should not. Therefore, we are regarding all the varieties of eggplant tested in Porto Rico as more or less equally susceptible to the Phomopsis blight.

It is of interest that color of fruit or of plant has no bearing on resistance. The white variety "Pompadour" is not so much less susceptible than the "Fajardo", a green-fruited variety. The

variety "Green", of green plant and fruit color, is almost as susceptible as the "University" variety—pink fruit—or the black purple fruited "Excelsior". (See Table I).

The Disease

NAMES

Various names have been applied to the disease. "Leaf-blight", "fruit-rot", "leaf-spot", "stem-blight", "foot-rot", "eggplant-blight", and "seedling stem-blight", all appear in the literature. In Cuba (**3**) two names have been given to a disease on leaves—*"mancha de la hoja"* (leaf-spot) and on stems—*"enfermedad del tallo"* (stem disease). These are in all probability the same disease. In Porto Rico we know it as "lunares de la hoja y tallo" and "podredumbre de la fruta".

HISTORY AND RANGE

The disease has probably been known since 1881 when Spegazzini described a new disease of eggplant which is probably the same as that under discussion here. There exists a doubt as to whether that disease is different from the Phomopsis blight. In New Jersey, Continental United States, Halsted (**6**) was the first to study the malady in 1890. Rolfs (**14**) reported it from Florida in 1893. Subsequently it has been reported from other States. It occurs in Italy and in Cuba and probably in all countries where the eggplant is grown. The first report from Porto Rico seems to be that by Stevenson and Rose (**24**). The fact that the disease has been found on new lands where vegetables had never been grown before suggests that it is endemic here.

IMPORTANCE

Vegetable growing in Porto Rico has been shown to be profitable during the season when early shipments can be made to the New York Market. It is to be expected that experienced growers may start a systematic development of this industry here. Since the eggplant is easily grown and handled it will naturally be one of the few vegetable crops to supply the demand. This plant also forms a part of the small patches of vegetables which are grown for the local market. A disease which usually brings about a loss of more than 50 per cent of the crop is certainly a serious menace and should have a more careful attention on the part of the growers.

MORPHOLOGIC SYMPTOMS

For convenience, the symptoms of the blight are given on large plants (transplants in the field) first and for these on leaves, stems and flowers and fruits.

The symptoms on the stem appear as lens-shaped, eye-shaped spots, regular in outline or long irregular cankers. On these the fruiting bodies of the fungus soon appear giving the surfaces of the spots a black-dotted appearance. These spots are first greenish or brownish, soon grayish to white except for the black fruiting bodies scattered throughout. The spots may appear in any location on the stem or branches. In cases of heavy infestations these occur at the crotches of the branches and stems. The seriousness of the spots at this location will be realized when one considers the effect of winds. The slightest breeze will break the branches at this point. When the spots arise farther up on the branches then the weight of the fruit will eventually cause the breaking of the branches. In heavily infested fields or when seedlings from diseased beds are used the pathogene gives rise to serious cankers at or near the surface of the ground. A large number of the plants will die before the first flower bud is out, but in some of them the effects of infection are masked even until the first fruit is picked. In these cases the main stem of the plant breaks at the place of infection where callous formation has proceeded. The terms "tip over" and "foot-rot" have been applied to this condition. Another effect of stem cankers is the girdling of the growing terminal bud in young plants which are beginning to blossom.

On the leaves the disease is more severe on the young transplants when the photosynthetic apparatus is so much needed. During rainy weather the spots appear as small circular to irregular areas between the veins. The color of these necrotic areas is a paler green than that of the blade of the leaf. Soon large irregular spots result. They coalesce, in many cases covering more than three-fourths of the entire blade. In some cases the growth of the fungus seems to become arrested, when the dried tissues of the dead areas break away, leaving holes of all sizes and shapes on the blades of the leaves.

A second kind of symptom is exhibited as small, circular, brown spots which never attain a diameter beyond one-fourth inch, usually being about one-sixteenth inch across. These lesions are characteristic of late infections during the drier months of February, March and April and in the older mature leaves. It is serious in that defoliation is brought about prematurely on the lower part of the bushes,

but sound fruits may be found on these. The fungus spores seem to be able also to penetrate the cuticle and epidermis of the midrib and veins producing lesions of a reddish color on most varieties and which may extend for an inch or two. The lesions may extend into the tissues on both sides of the midrib and veins. Long lesions on the midrib may cause the blade to break at that point.

The fungus attacks are quite serious on the petioles of the younger plants. Lesions here are lens-shaped or oval to elongated and sunken. They are brownish at first, then whitish, beset with the black tips of the fruiting bodies the same as the spots on the stems. The fungus sometimes extends from the spots on the petioles down towards the stem where it infects the young shoots which arise at the axils of the leaves. In severe cases the ragged, branchless condition is due to the plant being unable to replace these shoots.

On flowers and fruits the pathogen is very injurious. Flowers and very young fruits seem to be affected late in the season when abundant spores have been produced on the decaying leaves and fruits and on the stem cankers. When the fungus attacks the stalk of the flower or young fruit, the infections cause a shrinking of the tissues. The lesion may extend into the calyx and finally reaches the young ovary or fruit. In any case the ultimate result is the abnormal laying of an abscission layer and the flowers or young fruits drop to the ground. Yet small mummies may be occasionally found attached to the stem. The spots on fruit of all ages and sizes are first evidenced by brownish discolorations of not more than ⅛″ or ¼″ in diameter, usually of regular outline. Necrotic areas will appear at any point on the surface of the fruit but more frequently near the stem end. The fungus spores seem to lodge under the calyx lobes where ideal conditions for their incubation appear to exist. From there the dead areas spread in all directions, finally resulting in the destruction of the fruit. The symptoms will more frequently appear on overhanging fruit which touches the ground.

External symptoms on seed are seldom found. It has been definitely established (Sherbakoff **18**), that the fungus is carried with the seed. It is not very likely that seed may be separated into healthy and diseased. Usually seed from diseased fruit has all the appearance of normal healthy seed from sound fruit. It is only in very advanced cases of rotting that seed will be discolored.

Seedling stage.—On seedlings the morphologic symptoms given above for leaves and stems on full-grown plants usually exist. The rather crowded condition which prevails in the seedbeds is an in-

fluencing factor in determining the loss to seedlings. In very young seedlings an affection similar to that produced by the fungus *Pythium de Baryanum* Hesse, a bending-over resulting from the destruction of the young tissues at the surface of the ground, is produced.

Signs.—Pycnidia of the pathogene appear abundantly on the surface of lesions on stems, leaves and fruits. They are formed just beneath the epidermis, their beaks, when developed, extending beyond the surface. Ordinarily, beaks do not appear on the natural host except on very old lesions on plant parts which have dropped to the ground. However, they readily form on certain artificial media.

Histologic symptoms.—The most striking histologic symptoms is a hydrosis of the recently infected parts. The epidermal cells are the first to manifest this symptom and are followed in succession by the underlying cortex cells. The cells of the epidermis are more or less plasmolized. The cell walls of the epidermis as well as those of the cortex cells as far inward as the two or three outer layers of cortical parenchyma are stained brown. This discoloration of the cell walls has not been found to reach as far as the vascular bundles. In the case of lesions on the veins of the leaves and in the fruit, discoloration of the vascular bundles has been observed. In the small lesions on veins of leaves the fungus seems to stop its course after a short period of development. In the fruit the pigmentation is soon destroyed, the brown discoloration then appearing.

Etiology

Name, history and classification of the pathogene.—A number of diseases have been described on the eggplant which are probably identical. It is natural that various names should have been applied to the causal agent. In 1881, Spegazzini (**22**) described a new fungus on the eggplant leaves and fruit which he named *Phyllosticta hortorum.* Halsted (**6**) accepted this name for the fungus which he found in New Jersey in 1890 on leaves and fruit of the same plant. Halsted further attributes the damping-off or seedling stem-blight to *Phoma solani.* He evidently established differences between the various stages of the disease. It will be shown that the same fungus is able to produce lesions on all above-ground parts and in plants of all ages and therefore only one name should hold, either *Phyllosticta hortorum* Speg. or *Phoma solani* Hals. In 1904, Smith (**20**) reported the fungus *Ascochyta lycopersici* Brun, as different from what had been described as *P. hortorum* Speg. He found differences in size and septation of the spores and in the symptoms of

the leaves. In a later paper Smith (1905) was of the opinion that the seedling blight was also caused by this fungus. This year he regarded *Ascochyta lycopersici* and *Phyllosticta hortorum* as one and the same fungus. If they are really so and there is septation of the spores, then the former name would prevail and as Harter (13) rightly concluded, the name *Ascochyta hortorum* (Speg.) C. O. Smith should hold, for reasons of priority.

Voglino (25) extended into a consideration of the pathogene and designated his Italian fungus as *Ascochyta hortorum* (Speg.) Smith. Later, Harter (13) after examination and study of material from New York, Nebraska, New Jersey and Wisconsin found that the fungus was characteristically a member of the genus *Phomopsis*. His work is very illuminating. He concluded that this fungus and *Phoma solani* Hals. are identical. Saccardo and Sydow (15) had given the name *Phoma vexans* to Halsted's fungus because *Phoma solani* had already been applied to another species. Harter (13) then made his new combination *Phomopsis vexans* (Sacc. and Syd.) Harter. Harter had sent material to Spegazzini for comparison with type specimens of *Phyllosticta hortorum* and the latter apparently found them to be different. Therefore, Harter concluded that *Phyllosticta hortorum* had not been found in the United States. But Smith (20, 21) had found an *Ascochyta* and a *Phyllosticta* and had later accepted both to be the same fungus; and Voglino (25) had accepted Smith's views. Harter (13) was of the opinion that Smith had both an *Ascochyta* and a *Phyllosticta* on the same host. The latter would now be replaced by *Phomopsis vexans*. From host relationships and morphologic characters it appears that both Smith and Voglino had an *Ascochyta* which in Harter's opinion was *Ascochyta lycopersici* and hence distinct from the eggplant blight fungus.

The pathogene to which the disease is attributed in Porto Rico is characteristically *Phomopsis vexans* (Sacc. & Syd.) Harter. The fungus was not compared with any other from abroad because the writer thinks it has been thoroughly worked out by Harter and any further study on the taxonomic position would be a mere duplication of carefully done work. However, it has been given some attention.

Edgerton and Moreland (4) consider that the fungus exhibits variations in Louisiana in the manner of infection, rate and manner of growth and ratio of the two kinds of spores. We have not found much variation in our fungus. That apparently two kinds of spots were produced on the same plant made the writer believe that there

might possibly be two strains of the fungus. Not less than fifteen isolations from each type of lesion were made. All these pedigree cultures were compared in three media, oatmeal agar, corn flour agar and one per cent dextrose nutrient agar. The rate of growth of the different cultures is not given here because of the uniformity throughout. All the cultures produced a rapid growth in the dextrose agar, forming a thick creamy mycelial stratum over the medium which filled the entire dish (90 mm.) in seven days. Fruiting bodies were scanty in this medium and were formed on the edge of the colonies. In oatmeal agar and corn flour agar growth of mycelium was very slow. The size of the colonies was about 60 mm. in diameter on the seventh day in the oatmeal agar and about 50 mm. in the corn flour agar. Stromata began to develop in these media on the fifth day and large numbers had appeared on the twentieth day. The stromata are black. One to several pycnidia arise in each stroma in these media. The pycnidia are typically beaked. The beaks are from 1 mm. to 1½ mm. in length extending beyond the surface of the stromata.

The same cultures were used in cross-inoculation tests on egg-plant leaves and fruit. It was found that all the cultures from the supposedly different strains invariably produced the same symptoms when inoculated into these plant parts. The inoculations on leaves were made during rainy weather and the spots which resulted were of the large, irregular type. In no case was the small, circular spot reproduced. The writer, therefore, believes that the Porto Rican fungus is more or less uniform.

Harter's (**13**) description of the pathogene, p. 338 of his paper, is here given:

"*Phomopsis vexans* (Sacc. and Syd.), n. comb.
Phoma solani Hals., not *Phoma solani* Cooke and Hark.
Phoma vexans Sacc. and Syd.
Ascochyta hortorum (Speg.) C. O. Sm. not *Phyllosticta hortorum* Speg.

"On the foliage and stems pycnidia loosely gregarious in more or less definite spots, on fruit compact, at first buried, later erumpent, black without, beaked, flattened or irregular in shape, on leaves and stems 60 to 200 microns broad, on fruit 120 to 350 microns broad; pycnospores subcylindrical, somewhat acute, 5 to 8 by 2 to 2.8 microns, continuous, hyaline, 2-guttulate, rarely 3; basidia simple, short, straight or slightly curved, hyaline, continuous; stylospores filiform, curved, rarely straight, 13 to 28 microns long."

Stylospores were infrequently found in our material, both from

culture or from the lesions on the various affected parts. Pycnidiospores are generally found. The size of the latter as figured on the basis of 400 spore measurements is 5 to 8 × 1.3–3 microns. The size of the pycnidia agrees more or less with that given by Harter.

Life History

So far as known the fungus *Phomopsis vexans* is propagated asexually throughout its entire cycle.

Primary cycles may originate in the seedbed or in the field on leaves, stems, flowers or fruits.

Pathogenesis

Inoculation.—The fungus growing in a saprophytic condition in decaying vegetable matter gives origin to pycnidia where the asexual spores are produced in great numbers. These and the mycelium itself are the sources of the inoculum of the primary cycles.

Incubation.—None of the investigators that have dealt with this pathogene have ever succeeded in germinating the stylospores. The pycnidiospore (Phyllosticta type) germinates readily in distilled water or nutrient solutions at room temperaure in three and one-half hours. At the end of five hours germination is at its maximum.

The germ tube of a spore germinating on any above-ground plant part, either enters through a stoma or through a wound or penetrates through the cuticle into the epidermal cells.

Infection.—Infection begins in the epidermis. The germ tube becomes thicker and much branched in the epidermal cell. The branches invade the surrounding epidermal and cortex cells. The hyphae pierce through the walls of the cells, becoming slightly constricted at the point of passage into the next cell. In the larger parenchyma below the cortex the hyphae become profusely branched. (See plate VII, fig. 1). The whole cortex is soon involved and destroyed resulting in a sinking of the collapsed epidermis.

Saprogenesis

Phomopsis vexans is capable of a saprophytic existence in the soil. The fact that the disease has made its appearance in fields on new land which had never grown any Solanaceous species except tobacco, indicates that the fungus is susceptible of a prolonged saprophytic condition, although there exists the possibility of a wild non-solanaceous plant harboring it. In this phase pycnidia are prob-

ably produced abundantly and there is the least doubt that primary cycles originating on fruits and leaves are set up by the pycnidiospores from the saprophytic mycelium.

Secondary cycles are repeatedly occurring in a field where the pathogene is present. Pycnidiospores from lesions on decaying plant parts such as leaves from infected seedlings, affected flowers or fruit and stems start the secondary cycles. The most severe injury to plants is caused by these cycles.

Epiphytology

Outbreaks of the eggplant blight occur in Porto Rico at almost any time throughout the year if eggplants are grown. The writer has observed the disease during all the months between September and March. During one year (1927) when a crop was grown during the summer the plants were severely attacked towards the end of the season, in July and August. The temperature which prevails for the whole year seems to be adequate for the production of spores and their germination. Moisture probably regulates the appearance of the malady. Severe outbreaks always follow periods of light or heavy rainfall.

Control

It is very likely that control of this serious affection of the eggplant can be effected through crop rotation. Edgerton and Moreland (**4**) believe that a three-year rotation will be necessary.

Eradication through destruction of the after-crop is probably of little value in heavily infested fields. Much will be gained, however, if seedlings which show symptoms of the disease are destroyed as soon as detected. The removal of any plant in the field which bears the characteristic lesions should also be practiced. The fungus may be partially eradicated by seed treatment. It is a known fact that the mycelium of the fungus is actually present in the interior of the seed. This makes the effectiveness of treatment less likely.

The first treatments of seed for the control of *P. Vexans* were made by Sherbakoff (**17**) in 1916 using 1:10 formaldehyde solution for 10 minutes at 60° to 70° F. and 1:1000 corrosive sublimate for the same length of time at 80° to 85° F. He did not arrive at any conclusions that year. The same writer reported in 1927 (**18**) a 7 per cent contamination from non-disinfected seed and only more than 1 per cent for that disinfected in 1:1000 corrosive sublimate solution for 10 minutes. Sherbakoff (**19**) again in 1918 made further studies

with the disease and found that 1 per cent copper sulphate solution for five minutes destroys various bacteria and partly destroys saprophytic fungi on the surface of the seed. *Phomopsis vexans* was not affected by the treatment. Burger (**2**) in 1926 recommended the use of a 1:1000 corrosive sublimate solution for eight minutes for the disinfection of eggplant seed. He did not state which fungus he had in mind but it is assumed it was *P. vexans*, since work had been done previous'y with this pathogene in that Station. Edgerton (**4**) had reported in 1921 unsuccessful results in the elimination of *P. vexans* from seed by the use of a solution of one part commercial formaldehyde to 300 parts of water. The seed was kept in the disinfectant for fifteen minutes. He concluded that the formaldehyde treatment reduces the infection slightly but does not eliminate it.

From our own experience with the disease for three years we find it inadvisable to carry on treatments of seed. The results of tests made by other writers as given above shows that the mycelium within the seed is hard to be reached by any of the known practical disinfection methods. It seems more reasonable to insist on getting clean seed which comes from sound fruit. The production of clean seed is within the bounds of possibility. If seedsmen do not furnish seed guaranteed as coming from a clean source then the grower should grow his own seed. It is possible for him to select a number of good sound fruits and remove the seed which he can store away until the following season.

When growers do not grow their own seed and have to depend on unreliable sources, the next best thing to do is to exercise strict care in the seedbeds.

When clean, disease-free seed is sown on non-sterilized soil and the pathogene lives in that soil we are sure to get the seedling stage of the blight. In order to test the effectiveness of soil disinfectants in the control of the disease the following experiment was conducted.

Nine beds, $20' \times 3'$, the soil of which was known to be infested with *Phomopsis vexans* because a previous crop on the same beds had been seriously affected, were treated in the following manner: The first, second, third, seventh, eighth and ninth beds were drenched with a 1–50 formaldehyde solution, at the rate of one-half gallon per square foot of soil surface. The fourth and sixth beds received a drench of 4–4–50 Bordeaux mixture and the fifth bed remained as check. The seed was sown a week after treatment of the beds. Counts were made at time of appearance of symptoms in the untreated bed, at time of removal of seedlings to a second bed and

at time of transplanting. In the case of the check bed, bending-over of the seedlings occurred at an early age. The affected seedlings were removed and counted at that time. Tissue plantings from the tender stems of the affected lesions were made on artificial media to verify the presence of *P. vexans*. The organism was recovered in each case. The results of counts made at various intervals are collected and given in Table III. The large numbers of seedlings obtained in the beds may be accounted for by the fact that a considerable number was transferred to a second bed as soon as they developed two pairs of leaves. The second set of beds where these seedlings were planted and kept for five or six weeks before setting out in the fields, were sterilized in a manner similar to that given before. Of eighteen beds, twelve were treated with formaldehyde, four with Bordeaux mixture and two left untreated. The seedlings coming from the formaldehyde-treated beds were naturally transferred to those beds of the second set which had also been treated with formaldehyde. The same was true for the Bordeaux and check plots. In the second set of check plots, were planted only those seedlings from the check of the experiment which did not show any symptoms of the disease at the time of the transplanting from the treated beds. It should be noted that the seed used in this experiment was obtained from sound fruit grown by us.

TABLE III

EFFECT OF SOIL STERILIZATION ON THE SEEDLING BLIGHT OF THE EGGPLANT

Bed No.	Treatment October 15, 1928	Results—Seedlings			
		Healthy	Diseased	Total	Per cent diseased
1	1–50 Formaldehyde	6585	23	6608	0.35
2	1–50 Formaldehyde	5689	0	5689	No
3	1–50 Formaldehyde	6781	42	6823	0.62
4	4–4–50 Bordeaux	5007	892	5897	15.13
5	Check	51	6268	6319	99.19
6	4–4–50 Bordeaux	4989	1236	6225	.....
7	1–50 Formaldehyde	5437	0	5437	No
8	1–50 Formaldehyde	6897	37	6934	0.53
9	1–50 Formaldehyde	4979	0	4979	No

From an interpretation of the results of Table III it is evident that infested soils should not be used for eggplant seedbeds. Infested soils can be rendered safe for seedbeds if treated with formaldehyde, 1–50 solution at the rate of one-half gallon per square foot of soil surface. Very few plants were found with the disease

in beds treated in this way. An application of 4-4-50 Bordeaux mixture at the same rate as the formaldehyde solution gives fairly good results. The formaldehyde treatment is to be preferred because it practically eliminates the infestation and prevents secondary cycles. In the Bordeaux mixture treated beds some of the fungus escaped the action of the disinfectant or survived it, and spread rapidly over a large number of seedlings. The cost of the formaldehyde treatment in Porto Rico is as follows:

Formaldehyde (cost of material delivered at the Station), 11 gallons enough for 18 beds (20′ × 3′)-----	$24.75
Labor (application of formaldehyde)----------	3.00
Total----------	$27.75

This is the additional expense incurred when growing seedlings and does not include the cost of land, cultivation, etc.

Twelve beds were used as transplant beds as has been previously stated. These beds held about 900 seedlings each, the latter had been set at 3 inches apart each way. The twelve beds made a total of 10,708 seedlings. An examination of Table III will show that the six formaldehyde-treated beds yielded a total of 36,368 healthy seedlings. Those 10,708 seedlings in the twelve transplant beds given above proceeded from these 36,368 seedlings. The difference of 25,660 were left in the original beds and from there removed to the fields at intervals. From this number should be deducted nearly 2362 seedlings which were discarded from the original beds and which made up the number of diseased seedlings and those not planted because of poor development. The total of healthy seedlings, that could be used safely for planting was 34,006 and would have been sufficient to plant about five and one-half acres. The planting distances on which this calculation is based is three and one-half by two feet. The additional cost would have been about $4.50 per acre. A grower can easily afford this expense.

CONTROL BY PREVENTION

Attempts at the prevention of the malady were made as early as 1893 by Rolfs (**14**) who employed Bordeaux mixture and ammoniacal copper carbonate. No results are recorded. In 1895 Halsted (**7**) used Bordeaux mixture (5–5–50), Eau celeste (1–1½–50), copper sulphate (1. oz. to 8 gallons) and sulphide of potassium

(1 oz.–2 gallons) in an attempt to control the disease. Bordeaux was the only disinfectant which was satisfactorily applied. In 1896 the same writer (**8**) reported the testing of soda-Bordeaux, potash-Bordeaux and the 5–5–50 Bordeaux of his preceding year with the latter alone giving satisfactory control. The following year he (**9**) repeated the experiments adding this time a fourth fungicide, cupric hydrate, to those used in 1896. This year he found "little difference in the effectiveness of the four fungicides". In 1899 (**10**) Bordeaux and soda-Bordeaux were used but the number of fruits was not sufficient to be used in arriving at any conclusions. Halsted's (**11**) experiments of 1900 showed Bordeaux sprayings resulted in "less infested" plants and "somewhat larger" yields.

In 1921, Edgerton and Moreland (**4**) reported the results of four experiments with 4–4–50 Bordeaux mixture. Up to 13 applications of the mixture were made during a single season. There was a consistent increase in yield with applications of the fungicide but they concluded that it may not be practical to spray in Louisiana. Furthermore they found that "a few applications of the spray solution seem to have had no good effects". Yet they believe that in climates with less rainfall it may be profitable to spray.

Bordeaux mixture (4–4–50) has also been recommended by Bruner (**1**) in Cuba. Geise et al (**5**) reported in 1922 successful results in the control of *P. vexans* with copper lime dust and 4–6–50 Bordeaux mixture with 2 pounds powdered calcium arsenate. They obtained equally good control with both the dust and the spray. Spencer et al (**23**) found that Bordeaux with arsenicals gave satisfactory results. Bordeaux with zinc arsenite gave as good and in some instances better results than Bordeaux with calcium arsenate. Bordeaux dust with 20 per cent calcium arsenate was superior to Bordeaux dust alone or to the Bordeaux calcium arsenate spray (4–8–2–50).

It was deemed necessary to have a knowledge of the treatment for the control of the disease under the conditions which prevail in Porto Rico and especially in relation to its cost and practical application. One experiment was carried out in order to ascertain whether the blight of seedlings could be prevented by sprays. Three beds, $20' \times 3'$ each, were planted with eggplant seed as follows: the first bed, sterilized with formaldehyde and sown with seed coming from diseased fruits; the second bed, divided into two sections across the middle, in one section (*a*), the soil being sterilized with formal-

dehyde, and seed from diseased fruits employed. The second section (*b*) had soil which was known to be infested with the blight organism. Here seed from sound fruit was used. The third bed had soil known to be also infested with the pathogene and in it seed from sound fruit was used. Seed was planted on October 3, 1928. The first and third beds were sprayed every week with Bordeaux mixture (4–4–50), the first application being made on November 1st., when the first symptoms of the disease appeared. The second bed remained untreated. As soon as symptoms appeared on seedlings these were removed from the bed in order to reduce the source of inoculum as much as possible. A total of five treatments were made. At the time the fourth treatment was applied, Nov. 21, a large number of the healthy seedlings were of transplanting size and age and were removed from the beds. An additional treatment was then necessary for those which would reach the desired size in a week or two more. The results accumulated by the time when the majority of the plantlets were of the proper size for transplanting are given in table IV. The number of seedlings in the beds were small due to the fact that the sowing was made quite sparse.

TABLE IV

RESULTS OF 4–4–50 BORDEAUX TREATMENT FOR THE PREVENTION OF THE SEEDLING BLIGHT

Bed	Treatment	Seedlings			
		Healthy	Diseased	Total	Per cent Diseased
1 Formaldehydetreated. Seed from diseased fruit	4–4–50 Bordeaux	3231	893	4124	21.41
2a. Formaldehydetreated. Seed from diseased fruit	Check	1468	1509	2977	50.69
2b. Infested soil Seed from sound fruit	Check	1891	1686	3577	47.13
3. Infested soil. Seed from sound fruit	4–4–50 Bordeaux	3818	632	4450	14.20

The highest percentage of diseased seedlings (50.69 per cent) was on the bed with sterilized soil but where infested seed was employed. The infection in the untreated bed, with clean, sound seed, was lower only by a narrow margin.

It is plain that Bordeaux mixture has highly beneficial results in seedling blight prevention. When infested seed was used the effectiveness of the treatment was much reduced.

Notwithstanding the fact that rather fair control can be obtained by prevention we are of the opinion that one should rather endeavor to eliminate the infestation in the soil as has been recommended in the preceding paragraphs. One can easily see how apparently healthy plants may be carriers of the spores of the fungus which will infect the suscept when transplanted. A small amount of the diseases in a bed is a menace to the healthy seedlings in the same bed unless these are thoroughly wet with Bordeaux mixture previous to pulling for transplanting. Experience tells us that it is only with considerable difficulty that the fungicide is made to reach every above-ground part of the seedling. This is because of the rather crowded condition which holds during the fifteen or ten days which precede the operation of transplanting.

Experiments have been made to ascertain whether control of the disease in the field is possible and practical in Porto Rico. Bordeaux mixture of the formulas 4–4–50 and 3–3–50, and copper lime dust have been tried out. The results with the dust are to a certain degree misleading and will be omitted. Further and more extensive trials should be made before conclusions are drawn.

The plan of the experiments has been as follows. An examination of the field was made when the plants had developed about six leaves, this number including only one of the leaves of the partially expanded growing bud. All leaves that showed symptoms of the disease were gathered. At the time of the removal of the diseased leaves, records were taken of the number of diseased plants, number of diseased leaves, number of unaffected plants, number of plants with all leaves diseased, and the number of lesions on the leaves. These counts were made in order to have an idea of the general infestation of the field at the time of the first application. The number of lesions will give an idea of the number of inoculations, each spot representing, in our judgment, a distinct inoculation. The diseased leaves were removed from the field in order to make sure that any new lesions came as a result of inocula from other than the primary cycles.

In each experiment two rows on the edge of the particular field were kept as checks.

The results appear in Table V.

TABLE V

SHOWS RESULTS OF TREATMENTS FOR THE CONTROL OF EGGPLANT BLIGHT AND FRUIT ROT

	4-4-50 Bordeaux	3-3-50 Bordeaux
Total number of plants	1497	894
Total number of untreated plants (check)	63	121
Total number of treated plants	1434	773
Total number of plants with diseased leaves prior to treatment	517	396
Percentage of diseased plants	36.05	44.29
Total number of leaves	6674	5244
Total number of diseased leaves	979	935
Percentage of diseased leaves	14.67	17.83
Total number of lesions on leaves	6601	5002
Ratio of lesions to leaves	6.74:1	5.35:1
Total number of fruits at end of season on treated plants	6115	3772
Total number of sound fruit on treated plants	5976	3581
Total number of diseased fruits on treated plants	139	191
Percentage of sound fruit in treated plants	97.73	94.94
Percentage of diseased fruit on treated plants	2.27	5.06
Total number of fruits in "check rows"	137	206
Number of sound fruits in "check rows"	21	42
Number of diseased fruits in "check rows"	116	164
Percentage of sound fruits in "check rows"	15.33	20.39
Percentage of diseased fruits "in check rows"	84.67	79.61

An examination of Table V makes clear that the infestation of the three fields was very heavy. On the basis of number of plants the infection varied from 36.05 per cent to 44.29 per cent while on the basis of diseased leaves it would be much lower, 14.67 per cent to 17.83 per cent. The latter will probably better indicate the amount of infection at the time the treatments were made. The total number of lesions offers a still clearer idea of the general conditions of infestation. The counts of the lesions in all the diseased leaves throws a ratio of from 6.74 lesions per affected leaf to 5.35. This ratio is a clear expression of what was occurring in the fields at the time the treatments were made. Had no applications of fungicides been made the disease would surely have spread from the diseased to the unaffected plants.

The effect of the fungicides is calculated on the basis of sound to diseased fruit rather than on healthy or diseased foliage because of the difficulty in counting the leaves of the full grown plants throughout the season. A comparison of the results obtained with 3–3–50 or 4–4–50 Bordeaux mixture shows that the latter is more effective under more or less the same conditions of infestation. With the 4–4–50 Bordeaux mixture there were 97.73 per cent sound fruit as against 94.94 per cent for the 3–3–50 Bordeaux-treated field. The results in the check rows although with smaller numbers, show clearly

the danger to which the plants are exposed when no protection is employed.

The cost of Bordeaux mixture (4–4–50) and of its application at the Experiment Station are given here. These figures will apply to many sections of the island. The cost will, of course, vary according to the cost of labor and cost of transportation.

The cost of eight applications of the mixture was as follows:

43 pounds of copper sulphate at 7.7¢	$3.31
43 pounds of live lime CaO) at 1.8¢	.77
Cost of application, 118 hours of labor at 12.5¢ per hour	14.75
Depreciation of sprayers, estimated	2.00
Total cost of spraying 1,497 plants	$20.83
Cost per 1,000 plants	$13.91
Cost per 6,000 plants in about one acre	83.46

We have found that the cost of spraying eggplants in Porto Rico is highly prohibitive under ordinary conditions. Unless the cost of application is reduced it seems that our growers will not be justified in spraying. The solution of the problem of the cost of treatment lies in cheaper application or fewer applications. During certain years it may not be necessary to make as many as eight applications.

Probably the cheapest and safest plan of control of the blight and fruit rot is to grow healthy seedlings in the manner suggested in the preceding paragraphs and plant them in uninfested soils.

SUMMARY

1. A serious disease of eggplants known in Porto Rico as "lunares de la hoja y tallo" and "podredumbre de la fruta", in the United States of North America as leaf blight, foot-rot, leaf-spot, stem-blight, fruit-rot, eggplant-blight and seedling-stem-blight and in Cuba as "mancha de la hoja" and "enfermedad del tallo" exists in Porto Rico.

2. All varieties of eggplant are more or less equally susceptible under Porto Rican conditions. Color of plant or of fruit has no bearing on susceptibility or resistance.

3. The disease usually brings a loss of 50 per cent or over of the crop.

4. The symptoms of the disease appear on all above-ground parts of the plant. A seedling blight, stem and petiole cankers, spots on

leaf blades, fruit stalks and calices and a rotting of the young and mature fruit are produced.

5. The fungus may occur inside the seed.

6. The pathogene responsible for the malady is *Phomopsis vexans* (Sacc. & Sydow) Harter.

7. Variations of the fungus as have been observed elsewhere do not appear to occur in the fungus in Porto Rico.

8. The size of the pycnidiospores ranges from 5 to 8 microns in length to 1.3 to 3 microns in width.

9. The germ tube of a germinating spore may either enter through a stoma, enter through a wound or force its penetration through the cuticle.

10. Secondary cycles repeatedly occur in fields.

11. The fungus is capable of a saprophytic existence.

12. The prevailing temperature in Porto Rico seems adequate for spore germination.

13. Moisture is a very important factor in outbreaks of the disease.

14. The disease is probably controlled by a three- or four-years rotation.

15. Plants with the symptoms of the disease should be promptly removed from fields.

16. Although seed treatment is beneficial it never completely eliminates the pathogene.

17. Clean seed from unaffected fruit should be demanded.

18. Infested soils should be avoided in preparing seedbeds.

19. Inoculated soils can be rendered safe for seedlings if drenched with a 1–50 formaldehyde solution at the rate of one-half gallon per square foot of soil surface. An application of 4–4–50 Bordeaux mixture is highly beneficial but the formaldehyde treatment is to be preferred. The latter treatment will cost about two-thirds of one cent per seedling.

20. Bordeaux mixture (4–4–50) is quite effective in preventing seedling blight. The treatment is too expensive and therefore inapplicable under ordinary conditions. Bordeaux mixture may be of practical application where labor cost is reduced. The safest and cheapest control measure is to grow healthy seedlings and set them out in uninfested soils.

The writer wishes to express his appreciation to Dr. Melville T. Cook, Chief of the Division of Plant Pathology and Botany, for help in the final preparation of the manuscript.

Explanation of Plates

PLATE VII

Fig. 1. The fungus hyphae penetrating a cortical parenchyma cell from two adjacent cells. Note luxuriant growth inside the cell and the constriction of the hyphae at place of entrance.

Fig. 2. A fungus hypha in the cells below the epidermis.

Fig. 3. Conidiophores and conidia of *Phomopsis vexans* (drawn from the high power magnification).

Fig. 4. Germinating conidia (drawn from the oil immersion).

Fig. 5. Two plants affected with *P. vexans*. Note that there is only one healthy branch on the plant to the right. Stems, fruit and leaves, all severely infected.

PLATE VIII

Fig. 6. Lesions on stems. Note the black fruiting bodies on the whitish background of the lesion.

Fig. 7. Mummified fruits. Note that mummies are produced from fruits of all ages.

PLATE IX

Lesions on fruits of all sizes and age. Note the fruiting bodies on the fruit at the upper right hand corner.

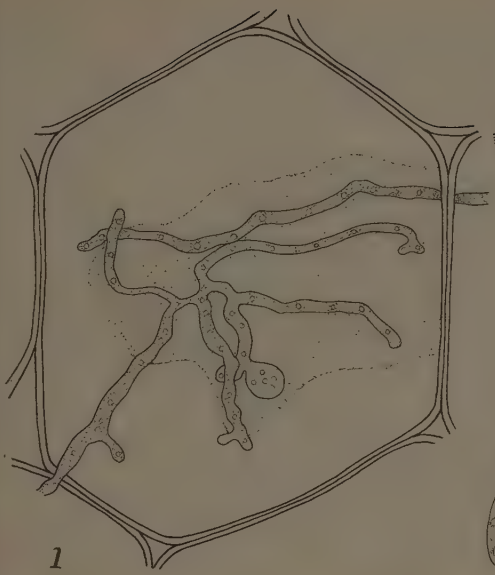
PLATE X

The lesions on the leaves. Note two types of spots and also the fact that lesions are produced on the veins and parts of the blade between the veins.

LITERATURE CITED

1. **Bruner, Stephen G.** Enfermedades de la berenjena. Cuba Est. Agron. circ. 53: 1–20, pl. 1–6. (No date.)
2. **Burger, O. F.** Report of the plant pathologist. In Florida Agr. Exp. Sta. Ann. Rept. **1926**: 68–84.
3. **Cook, M. T.** and **W. T. Horne.** Insectos y enfermedades de las hortalizas. Cuba Est. Cent. Agron. Bul. 12: 3–32, pl. 1–8. 1908.
4. **Edgerton, C. W.** and **C. C. Moreland.** Eggplant blight. Louisiana Agr. Exp. Sta. Bul. 178: 1–44, figs. 1–18. 1921.
5. **Geise, Fred W., H. H. Zimmerley** and **H. Spencer.** Truck Crop Investigations. Spraying and dusting vegetable crops in 1922. Virginia Truck Expt. Sta. Bul. 41: 237–256, fig. 49–57. 1922.
6. **Halsted, B. D. Report of the botanical department.** In New Jersey Agr. Exp. Sta. Ann. Rept. **1891**: 235–340, figs. 1–24. 1892.
7. ----------, -----. -----. Report of the botanical department. In New Jersey Agr. Exp. Sta. Ann. Rept. **1895**: 247–361, fig. 1–70. 1896.
8. ----------, -----. -----. Report of the botanical department. In New Jersey Agr. Exp. Sta. Ann. Rept. **1896**: 289–429, fig. 1–63. 1897.
9. ----------, -----. -----. Report of the botanical department. In New Jersey Agr. Expt. Sta. Ann. Rept. **1897**: 261–394, fig. 1–40. 1898.
10. ----------, -----. -----. Report of the botanical department. In New Jersey Agr. Exp. Sta. Ann. Rept. **1899**: 321–419, fig. 1–16. 1900.

11. ----------, ----. ----. **Report of the botanical department. In** New Jersey Agr. Exp. Sta. Ann. Rept. 1900: 405–476, pl. 1–12. 1901.
12. ----------, ----. ----. **Report of the botanical department. In** New Jersey Agr. Exp. Sta. Ann. Rept. **1906:** 369–514, pl. 1–25. 1907.
13. **Harter, L. L.** Fruit-rot, leaf spot, and stem-blight of the eggplant caused by Phomopsis vexans. U. S. Dept. Agr. Jour. Agr. Res. **2:** 331–338, **pl.** 26–30, 1 fig. 1914.
14. **Rolfs, P. H.** Report of the Botanist and Entomologist. **In** Florida Agr. Exp. Sta. Ann. Rept. **1893:** 1–31, fig. 1–5. 1894.
15. **Saccardo** and **Sydow.** Sylloge Fungorum **14:** 889. 1899.
16. **Sherbakoff, C. D.** Report of the Assistant Plant Pathologist. **In** Florida Agr. Exp. Sta. Ann. Rept. **1915:** 94–98.
17. ----------, ----. ----. **Report of the Assistant Plant Pathologist. In** Florida Agr. Exp. Sta. Ann. Rept. **1916:** 80–98, fig. 12–16.
18. ----------, ----. ----. **Report of the Associate Plant Pathologist. In** Florida Agr. Exp. Sta. Ann. Rept. **1917:** 76–86, fig. 3–8.
19. ----------, ----. ----. **Report of the Associate Plant Pathologist. In** Florida Agr. Exp. Sta. Ann. Rept. 1918: 68–78, fig. 10–13.
20. **Smith, C. O.** A new eggplant fungus. Jour. Myc. **10:** 98–99, fig. 1–6. 1904.
21. ----------, ----. ----. **The study of the diseases of some truck crops** in Delaware. Delaware Agr. Exp. Sta. Bul. 70: 1–16, fig. 1–6. 1905.
22. **Spegazzini, Carlos.** Nova addenda ad Mycologiam venetam. Atti, Soc. Crittog. Ital. **ann. 24, s2, 3:** 42–71. 1881.
23. **Spencer, Herbert; H. H. Zimmerley** and **Ray J. Davis.** Truck Crop Investigations. Dusting and Spraying eggplants. Virginia Truck Exp. Sta. Bul. 47: 331–347, fig. 69. 1924.
24. **Stevenson, John A.,** and **R. C. Rose.** Vegetable diseases. **In** Porto Rico Ins. Exp. Sta. Ann. Rept. **1916–1917:** 83–88. 1917.
25. **Voglino, Pietro.** Intorno ad un parassita dannoso al **Solanum Melongena.** Malpighia, ann. **21:** 353–363, pl. 4. 1907.
26. **Weber, G. F.** Field work in Florida during the year on disease control. Florida State. Pl. Bd. Quart. Bul. **8:** 1–28. 1923.



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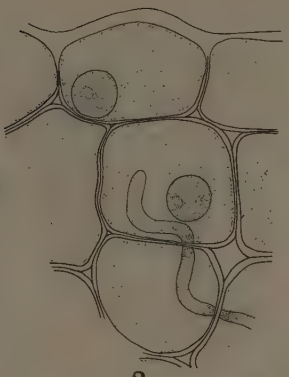

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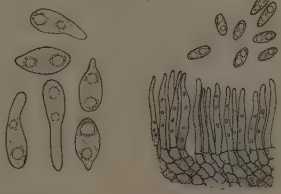

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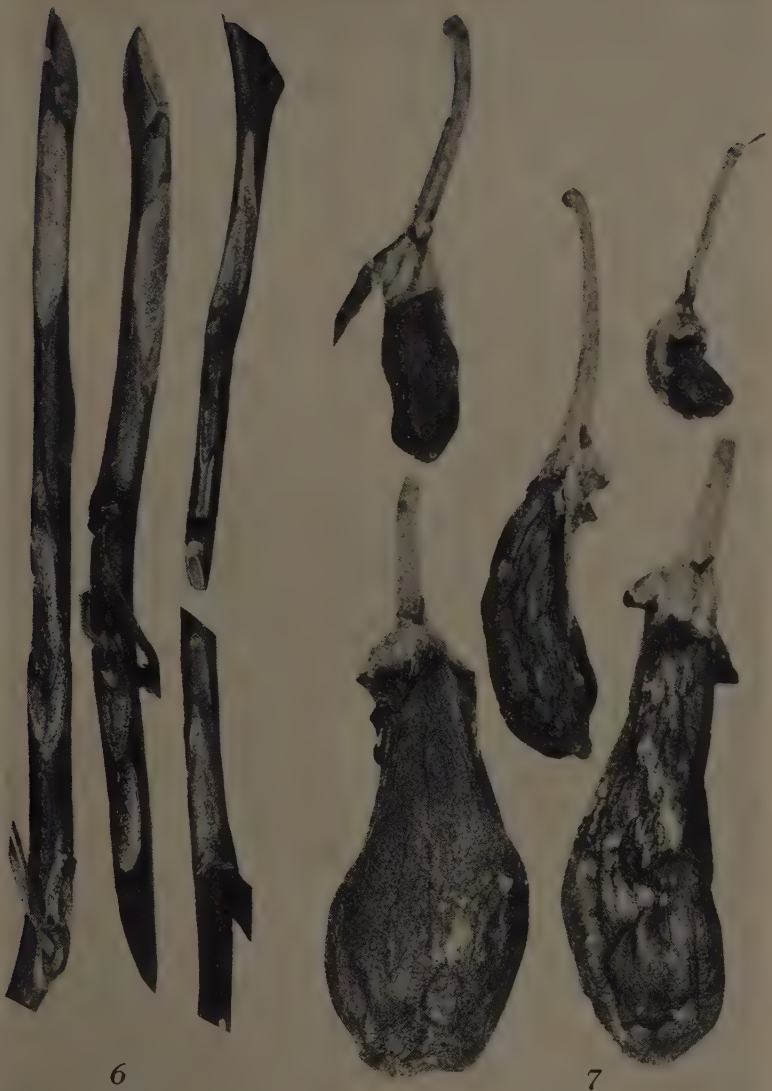

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PLATE IX.

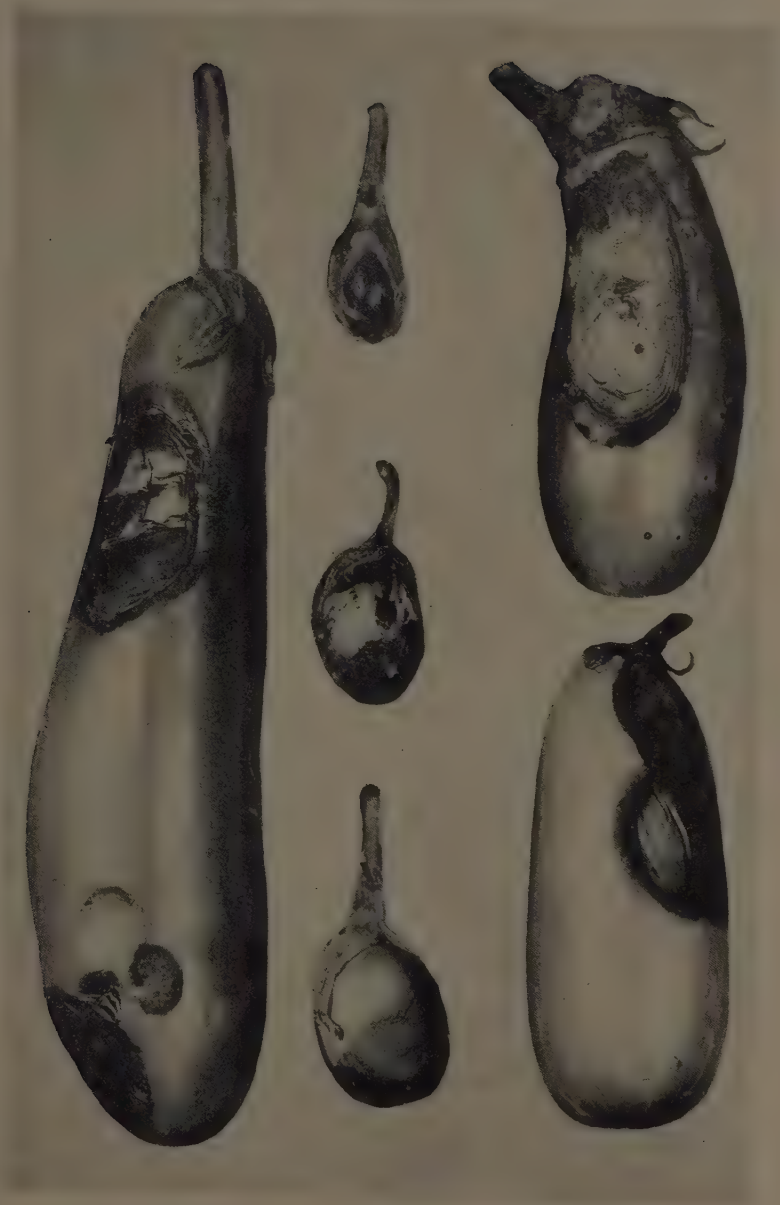

PLATE X.

ACROSTALAGMUS APHIDUM OUD. AND APHID CONTROL

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The control of aphids through fungous parasitism has attracted much attention during the last two decades. Johnston (**1**) was the first one to call attention to the existence of fungi on aphids in Porto Rico, which he regarded as important in the control of this pest. The present paper deals with a study of *Acrostalagmus aphidum* Oud. with special reference to its use in the control of some plant lice.

In 1915 Jones (**3**) reported the fungus *Acrostalagmus albus* Preuss. on the sugar cane aphid *Sipha flava* Forbes. During the same year Johnston (**2**) in his description of the entomogenous fungi of Porto Rico gave this fungus on various hosts. In 1926, the writer's attention was called to the parasitizing action of this fungus on the aphids of the melon in a planting in the interior of the island. Preliminary studies were made that year. These were followed by more extensive field trials in 1927 and 1928. Because the fungus and been reported in Porto Rico under the name of *Acrostalagmus albus,* and the description did not agree with that offered in Saccardo for that species, material was sent to the United States Department of Agriculture Bureau of Plant Industry for determination. Miss Vera K. Charles of that Bureau, after a comparison with a number of species of Acrostalagmus concluded it was *A. aphidum* Oud. and not *A. albus* Preuss. It should be noted that Johnston (**2**) had found considerable difference between the type and his Porto Rican form but regarded it as "scarcely enough to indicate a separate species." Although the writer finds differences between the morphology of the Porto Rican form and the description in Saccardo, which may be considered enough to erect at least a distinct variety or strain he has retained the name *Acrostalagmus aphidum* Oud.

A study of the fungus has been made both on its natural and on artificial strata. Normally a profuse white to creamy mycelium develops on the surface of the parasitized insects. The mycelial threads are slender, siphonaceous, mostly dichotomously branched. Asexual spores are abundantly produced on erect fertile hyphae.

These spore-bearing threads are occasionally septate but more usually continuous. They fork out into three to four branches two or three of which bear spores at the tips and one usually grows out and branches again giving rise to more condiophores (see Plate XI, fig. 10). The usual number of these branches is three. Conidia are borne singly or in heads (see Plate XI, fig. 7–10). They are oblong, cylindrical or elliptical, obtuse on both ends or slightly pointed at one, hyaline, non-septate; the size of the Porto Rican form varies from 3–14 $\times$ 1–4 microns, and has a mean of $7.259 \pm 0.0717 \times 2.47 \pm 0.02$ microns. The exact manner of head formation has not been clearly established. From observations of germinating spores if seems that the spore heads are formed as follows: The first conidium formed becomes detached from the tip but does not fall off. It seems to be enveloped by some sort of a mucilaginous substance which prevents it from falling off. A second conidium is produced at the tip, and others follow in succession all remaining together in a head-like structure held by an apparently evanescent film (see Plate XI, fig. 8).

Measurements of conidia were made from various hosts. The differences found in the size of the spores from the various natural strata (different species of aphids) are insignificant. Some of the results appear in Table I.

TABLE I

LENGTHS AND WIDTHS OF CONIDIA IN MICRONS—FUNGUS ON THREE DIFFERENT STRATA

Stratum	Lengths				Widths			
	Minimum	Maximum	Modal class	Mean	Minimum	Maximum	Modal class	Mean
Okra aphid	3.95	11.84	6.0	7.055 ± 0.0699	1.32	3.42	3.0	2.616 ± 0.271
Eggplant aphid	3.45	13.11	7.0	7.259 ± 0.0717	1.04	3.45	2.5	2.47 ± 0.020
Oatmeal agar	3.16	10.52	6.0	6.028 ± 0.055	1.32	2.63	2.0	2.265 ± 0.022

A biometrical consideration of the results indicates that the difference in mean spore lengths in the fungus growing on the bodies of the eggplant aphid and that on the oatmeal agar is significant,

about thirteen times its error; as is the difference between the okra aphid fungus and the fungus on the oatmeal agar, its error being contained in it about 11 times. On the other hand the little difference between the okra aphid and the eggplant fungus spore mean lengths falls within the limits attributed to random sampling. In the mean widths of spores, however, it appears that there is only a significant difference, seven times its error, between the fungus on the eggplant aphid and the culture on oatmeal agar. Here the greater mean width is found in the former and agrees with the results on lengths of spores.

A further consideration of the figures on the table shows that our measurements vary somewhat from those given in the original description for *A. aphidum* Oud. Thus, there the size of conidia is given as 7–14 × 2.5 microns. Our results show a wider range of spore length and width. From the table we find that the measurements for the Porto Rican fungus are 3–14 × 1–4 microns with a mean size of 7.259 ± 0.0717 × 2.47 ± 0.02 microns.

The description of the fungus is here inserted as taken from Saccardo's "Sylloge Fungorum":

"*Acrostalagmus aphidum* Oud. Beitr. Bot. Centr. 1902, p. 15. Syll. 18: 536–37. Caespitibus effusis, tennibus, albis, hyalinis; hyphis sterilibus repentibus, ramosis, continuis; fertilibus erectis, sursum trifucatis, ramis secundariis primario aequilongis v. longioribus, continuis, summo subulato, capitulo conidiorum capitato-aggregatorum, muco conglutinatorum 12–16 micr. diam. one-ratis; conidiis oblongis, hyalinis, continuis, cylindraceis, rectis, utrinque obtusis, 7–14 × 2.5.

Hab. in sceletis Aphideae cujusdam, in superficie foliorum Aristolochiae gigantis in horto botanico Utrecht Hollandiae."

Nederl. Kruidk. Arch. Ser. 3, Vol. 2, p. 759 (1902)

Acrostalagmus aphidum Oud.—Sur les squelettes accumulées d'une Aphidée, a la surface des feuilles languissantes d'un *Aristolochia gigas*, cultivé dans une serre chaude du Jardin botanique d'Utrecht, le 13 Oct. 1900.—Mr. A. Pulle, candidat en histoire naturelle.—Touffes éparses, subtiles, blanches, hyalines sous le microscope. Hyphes steriles rempantes, rameuses, continues; fertiles dressées, trifurquées au sommet, a branches aussi longues ou plus longues encore que la hyphe-mére, continues, pourvues a leur sommet subule d'une agglomération sphérique de conidies, retenues en place par une matiére glutineuse, large de 12 a 16 p. Conidies nombreuses, oblongues, hyalines, continues, droites, arrondies aux bouts, 7–14 × 2–1/5.

Spore germination.—Studies were undertaken with the object of

finding out the optimum conditions for spore germination. In all cases fresh spores were used as the results would give an approximation to what occurs in nature. Drops from a spore suspension in tap water were placed on slides and kept in a moist chamber. In another set the drops were placed in Van Tieghem cells and likewise placed in a moist chamber. Observations showed that the germ tubes began to protrude at the ends, after two hours and forty minutes. A count of the spores that had germinated and those that had not was made at the end of six and one-half hours. Of 884 spores counted in the drops on the slides, 604 germinated and 280 failed to do so. This shows a 68.33 per cent of viable conidia.

It has been observed that some of the conidia become one-to several-septate prior to or after germination. At the end of several hours of germination, conidia are produced at the tips of the branches of the fertile hyphae. In some of the branch tips a bulged-out affair is only formed with no evidence of the conidia. Some of these structures have been seen to function in germination like the conidia (see Plate XI, fig. 7). The heads are soon formed and at the end of ten or twelve hours may contain as many as four or five spores. Some of the young conidia will germinate while still attached to the head-like fruiting structure (Plate XI, fig. 6).

It was observed that some germinating conidia send out dark structures at the end of the germ tubes, which resemble and function like the appresoria of the anthracnoses (Plate XI, fig. 5). These secondary bodies and the germ tubes which bear them become brown. They have always been found where the moisture present during the early stages of germination was lost and therefore development was temporarily arrested. When moisture is restored these germinate by sending out long germ tubes or short, fertile branches. This again likens them to the appresoria of some of the Melanconiales.

Germination in sugar solutions.—Suspension of fresh spores were prepared on 10 per cent sucrose and 10 per cent glucose solutions and in distilled water. Drops were placed on slides and allowed to germinate in the usual manner. Germination started simultaneously in the check and the two sugar solutions. Counts made at the end of five hours showed that 78.365 per cent of the spores in distilled water, 89.795 per cent in the sucrose solution and 97.80 per cent in the glucose solution had germinated. Undoubtedly there was a marked favorable effect of the glucose on germination. Germination was somewhat higher in the sucrose solution than in distilled water. Although the lengths of the germ tubes were not measured at the

time, it was clear to the writer that the much longer germ tubes were found on the spores germinating in the glucose solution.

Dessication of spores.—To determine the effect of drying on conidia, a suspension of these was made in distilled water and drops placed on slides. The drops of water were dried from the slides by operating an electric fan. Two slides were left without drying the water film and the spores allowed to germinate in a moist chamber. These served as a check. The slides with the dried films of water were divided in two sets, one of which was placed in dry chambers and the other in moist chambers. Tests for viability of the conidia were made on the following day. Upon examination of the slides in the moist chambers it was found that a considerable number of the conidia had germinated. The same thing happened in the checks. By the third day most of them had sent out germ tubes.

In the dry chamber set, the germinating power of the spores was rapidly lost. On the third day only about 33 per cent were viable; while on the fifth day only 8 per cent retained the germinating ability and on the sixth day none of the spores germinated. It is thus demonstrated that spores germinate readily in the presence of a small quantity of moisture and that their germinating power is hindered by dessication, retaining their ability to germinate for only five days in the absence of moisture.

Effect of aphid extracts on germination.—To ascertain whether extracts of the insect juices had any effect on the rate of germination of conidia, a considerable number of aphids from two hosts were gathered, macerated and the extract obtained in distilled water. The small portions of the bodies of the insects were removed from the extracts. A suspension of fresh spores was then made in each of the two extracts and indistilled water. Drops were placed on slides and those in germinating chambers. The lengths of the conidia and germ tubes were measured at the end of six and one-half hours. The results are given on Table II.

TABLE II

LENGTHS IN MICRONS OF GERMINATING CONIDIA ON VARIOUS MEDIA

Extract of	Lengths			
	Minimum	Maximum	Mode	Mean
Cryptostegia aphid	13.80	124.20	24.15	41.45 ± 0.795
Cyperus aphid	10.35	86.25	24.15	29.60 ± 0.5882
Distilled water	9.35	62.10	13.80	19.159 ± 0.2511

A glance at the table makes evident that a pronounced difference in mean length of tubes exists on germination spores in aphid juices as compared to distilled water. This difference is about 10.44 microns for the spores on the *Cyperus* aphid juice and is about sixteen times its error. The difference between the mean lengths of germ tubes in the *Cryptostegia* aphid juice and distilled water is 22.291 microns which is nearly twenty-seven times its error and therefore highly significant. Further, the difference of mean lengths of tubes in the two juices is 11.85 microns, about twelve times its error. The mean lengths are significant to the point of indicating a stimulating effect of aphid juices on germination and suggesting variations in this influence according to the species of aphids. (See Plate XI, fig. 1–4).

Effect of reaction on growth of the fungus.—The fungus was grown in Bouillon and in a culture solution No. 1 * of pH values ranging from 2.94 to 9.44. The results are given in Table III.

TABLE III

EFFECT OF REACTION ON GROWTH OF *A. APHIDUM*

pH	Solution No. 1	Bouillon
2.94	—	+— —
3.94	+—	+—
4.94	++	+
5.98	+++	++
6.93	++++	+++
7.03	++++	+++
7.93	++++	+++—
8.90	+++	++
9.44	+—	+—

In the table degree of luxuriance of growth is represented by crosses, four + 's standing for optimum development and +— for slight growth. This organism seems to produce optimum growth in media of the reaction 6.93 to 7.93, from almost neutral to slightly alkaline. Growth ceases in acid concentrations of pH 2.94 and only a slight development occurs in reactions of pH 9.44.

HOSTS

As has been stated before the pathogene was reported on *Sipha flava* (**3**). In 1915 Johnston (**2**) reported the fungus on the following hosts: *Sipha graminis* on *Saccharum officinarum* L., the *Eupatorium odoratum* aphid, and the dead bodies of the aphid on okra

* *Formula.* Cane sugar 60 gms., ammonium phosphate 0.6 gms., magnesium sulphate 0.25 gms., ferrous sulphate trace, and water to make 1,500 c. c. Reaction adjusted to lower concentrations with tartaric acid.

(*Abelmoschus esculentus*, (L) Moench.). It seems that Johnston made a slight error in giving the sugar-cane aphid as *Sipha graminis*. Stevenson (**4**) in 1918 added *Corythaica monacha* on *Solanum melongena* to the list of hosts given above.

Wolcott (**5**) cites Van Zwaluwenburg (**6**) as reporting *A. albus* on the coffee aphid *Toxoptera aurantiae* Boyer. Table IV gives a summary of the hosts of this pathogene in Porto Rico.

A number of the host plants of the aphids are marked with one or two stars while others are unmarked. Those plant hosts with one star had been reported previously, those with two stars are first recorded here while on those without any star the fungus has not been found or reported as yet. The genera and species of aphids with one star are those first found by the writer to be parasitized by the fungus

TABLE IV

HOST RELATIONSHIPS OF *A. APHIDUM*

HOST OF THE FUNGUS	PLANT HOST
Aphis gossypii Glover	Cotton—*Gossypium barbadense* L. * Okra—*Abelmoschus esculentus* (L.) Moench. * Cucumber—*Cucumis sativus* L. ** Melon—*Cucumis melo* L. Guava—*Psidium Guajaba* L. *Cecropia peltata.* ** "Yautía"—*Xanthosoma sagittaefolium* (L.) Schott. ** "Malanga"—*Caladium colocassia* (L.) W. F. Wight.
Rhopalosiphum persicae Sulzer	* Eggplant—*Solanum melongena* L. * Pepper—*Capsicum baccatum* L. Sweet potato—*Ipomoea batatas* L. Sesame—*Sesamum orientale* L.
Toxoptera auriantiae Boyer	* Coffee—*Coffea arabica* L. * Orange—*Citrus sinensis* (L.) Osbeck. ** Mamey—*Mammea americana* L. Cacao—*Theobroma cacao.* ** Grapefruit—*Citrus grandis* (L.) Osbeck. Sea-grape—*Coccolobis uvifera* (L) Jacq. Mirto—*Chalcas exotica* (L.) Millsp.
Sipha flava Forbes	* Sugar-cane—*Saccharum officinarum* L. Sorghum—*Holcus sorghum* L. Lemon grass—*Cymbopogon citratus* (DC) Stapf.

HOST RELATIONSHIPS OF *A. APHIDUM*—Continued

HOST OF THE FUNGUS	PLANT HOST
Corythaica monacha Stal. (eggplant lace-bug)	* *Eggplant—Solanum melongena* L.
* *Aphis pseudobrassicae* Davis	** Cabbage—(*Brassica cleracea* L.) Mustard—(*B. integrifolia* (West) O. E Schulz)
* *Carolinaia cyperi* Ainslie.	** "Coquí"—*Cyperus rotundus* L.
* Undetermined aphid	** *Cryptostegia madagascariensis*
Undetermined aphid	* *Eupatorium odoratum*

Inoculation experiments.—The first work done with this problem was in December of 1926. At that time there occurred a very heavy infestation of the aphid *Rhopalosiphum persicae* on eggplants which were being grown for breeding purposes. The writer discovered a number of plants the leaves of which showed on the under surface an abundance of small white, cushony-like masses, which upon closer examination proved to be dead bodies of aphids covered with mycelium of the Acrostalagmus fungus. Simultaneously the writer had collected melon leaves in Cayey, P. R., which also showed the parasitized bodies of aphids. Cultures were made from the dead bodies of both the melon and eggplant aphids. Cucumber and eggplant seedlings were grown in pots in the green house. When the eggplant had attained a height of eight inches and the cucumber vines were about two feet in length they were exposed for a day in places where it was known infestation of each host would come about. When the plants showed the aphids on the lower surfaces of the tender leaves they were removed to the greenhouse with care not to shake off the plant lice. There the insects were allowed to multiply. The plants were next put inside cages (cheese cloth-lined) and here sprayed with a suspension of the Acrostalagmus spores. This operation was performed on an evening just before sunset. Spores of the fungus both from dead aphids and from corn meal agar cultures were employed. There were in the experiment three sets of eggplant and three of cucumber plants. In each case one set was left as check, a second one sprayed with spores from the corn meal agar culture and the third received the suspension of spores from the fungus growing on dead aphids. After inoculation the cages were kept moist for two days so as to insure adequate moisture relations for the germination of the spores. Daily observations were made. At the end of the third day a few aphids in each inoculated cage were found to show a slight brownish discoloration (not the browning

induced by the insect hyperparasites). The number of dead insects increased every day until the end of one week when the majority had succumbed to the attacks of the pathogene. In fourteen days all the aphids in the inoculated cages had died. This experiment demonstrated that either the melon or eggplant aphid fungus had the ability of parasitizing the aphids on either the eggplant or cucumber. The cucumber and the melon aphids are identical. That the melon aphid fungus and the eggplant aphid fungus were one and the same was corroborated by further cross-inoculations on pepper, eggplant, cucumber and melon, and by microscopic examination. The aphid on the eggplant and pepper is the same species. The details of these inoculations are omitted because the method is the same as described above.

It was planned to inoculate as many species of aphids and on as many hosts as could be found in abundant numbers or could be grown in the greenhouse. In November 1927, a number of sprouts arising from a "mamey" (*Mammea americana*) stubble exhibited a curly appearance of their more tender leaves. Upon examination they were found to be covered on the under surface by a considerable number of plant lice. These were soon sprayed on a cool afternoon with a suspension of the spores of Acrostalagmus. Death of the insects was brought about in from six to twenty days. This is a new record of parasitism of the fungus on the species which had been reported (**6**) as attacked on coffee and orange.

In the month of December of that year the fungus was found on okra (*Abelmoschus esculentus*), and again on the melon aphid, on eggplant, pepper and cucumber. Inoculations from each of these were performed on the eggplant aphid with successful infection. The aphid on the okra was also inoculated with the fungus isolated from the dead insects on this host and it also died.

The fungus made its reappearance during the months from October to February (1928–29) on the aphids on the following plants: eggplant, pepper, cucumber and okra. New isolations were made this year and used in the inoculations which are given later.

In December, 1928, a number of "coquí" (*Cyperus rotundus*) plants were examined for the presence of aphids. It was discovered that a number of the insects had been killed by a whitish fungus and *Acrostalagmus aphidum* was suspected as the causal agent. Isolations were made and the cultures employed in cross-inoculation studies.

A search was made for different species of aphids and on different hosts. In January we discovered abundant aphids on the following

hosts: eggplant, cabbage, (*Brassica oleracea* L.), mustard (*B. integrifolia* (West) O. E. Schulz), "coquí" (*Cyperus rotundus*), "yautía" (*Xanthosoma sagittaefolium* (L.) Schott), "malanga" (*Caladium colocassia* (L.) F. W. Wight, *Cryptostegia madagascariensis* (a recent introduction from the botanical garden of Panama, Central America), on grapefruit (*Citrus grandis* (L.) Osbeck and on corn (*Zea Mays* L.). All the aphids on these hosts were inoculated with a suspension of the spores of the fungus isolated from the eggplant aphid. The "coquí" aphid was in addition sprayed with the spores of the culture obtained from the dead aphids on this host. All the aphids except those on corn were killed by the fungus.

The results of these inoculations prove the similarity or identity of the *Cyperus rotundus* aphid fungus and the eggplant aphid *Acrostalagmus*, because the *Cyperus* aphid is killed by both fungi. The results also add aphids of two other genera and an undetermined one on four plant hosts to the list of suscepts of *A. aphidum*. The fungus has been shown to infect the aphid *Toxoptera auriantiae* Boyer on two other hosts (grapefruit and "mamey"), which the aphid may attack. (See Table I.)

The fungus did not kill the corn aphid under natural conditions. Mr. Seín, the Assistant Entomologist showed to the writer a number of corn aphids which he had kept in a culture dish and which happened to be covered with a whitish mycelium, similar to that of *A. aphidum*. A microscopic examination showed the fungus to be *A. aphidum*. Further trials were therefore made with this aphid. A small number, about 30, of insects with a few fragments of corn leaves were put in each of two large culture tubes (200 × 25 mm.) About 4 c. c. of a suspension of spores of the fungus were added to one of the tubes. The tube was kept under fair conditions of humidity by a piece of moist cotton which hung from the mouth. The mouth of the tube was stopped with a double thickness of cheese-cloth. Observations were made daily. At the end of six days all the aphids were alive in the two tubes. At the end of ten days no more corn-leaf fragments were put in the tubes. Twelve days after the experiment was started a large number of aphids had died in both tubes. It was then that the fungus mycelium was first appearing on the dead bodies of the aphids from the inoculated tube. We interpret these results as indicating that the fungus is not capable of parasitizing the corn aphid but that it may live on the dead bodies of the insect in a saprophytic manner. Had the death of the insects been brought about by the infection produced by the

fungus then we would have expected some dead bodies in four to eight day, as is the case in the susceptible aphids.

The application of aphid control by *Acrostalagmus aphidum* in the field. Following our preliminary experiments in the green-house in December, 1926, field trial were effected in an effort to control the aphid *Rhopalosipum persicae* Sulzer on the eggplant. A plot intended for breeding purposes showed a severe infestation of the insects toward the latter part of that month. A suspension of the spores was prepared from cultures and from the dead bodies of the aphids. This was sprayed during a cool afternoon with an atomizer over the lower surfaces of the leaves where the aphids were feeding. The majority of the plants in alternate rows were treated in this manner. Only the aphids on a few of the leaves on each plant received the inoculum, as the treatment of all the leaves on each plant would have required too much labor and a considerable quantity of the spore suspension. The days following the inoculation were attended by cloudy weather with light intermittent rains. Under these conditions the fungus developed luxuriantly on the suscept insects. At the end of the first week the majority of the insects on the sprayed plants were dead. From these the inoculum was transported to the neighboring uninoculated plants and in fourteen days the infection of the insects had extended over the entire field. In less than three weeks the greater part of the aphids were parasitized by the fungus. The results were convincing. Control of the aphids in the field was possible by this simple method.

Three weeks later a short period of rains occurred. The weather was favorable for the multiplication of the aphids and therefore a new infestation came about. No longer had the aphids begun to increase in numbers than infection of their bodies with the fungus ensued. The pathogene seemed to have lived in the soil and from here the inocula was transferred to the aphids. These results showed first, that only one inoculation of the aphids is required in a field, and second, that the fungus lives in some saprophytic manner in the soil.

Eggplant has been grown in this same field during the last two years, September-December, 1927 and 1928. In both years aphids have appeared during rainy periods. However, a recurrence of the aphid fungus held them in check each year. This is a lucky circumstance since it indicates that once a field is inoculated with the fungus the latter may persist for a number of years. Our experience with the fungus covers only a period of three years and further

observations should be made in succeeding years to verify its presence or disappearance.

Our field experiments have been conducted on the eggplant alone. The encouraging results in this crop should give a start to more extensive trials on other crops. From his observations the writer is convinced that an equally successful control can be secured on the aphids of the melon, cucumber, okra and other crops. On such plants like the melon, cucumber and cabbage control is probably more effective because of the foliage being closer to the soil. The inoculation experiments discused previously point to a wide range of species and genera of aphids that are parasitized by the fungus. A good many of those species are of economical importance.

Control of aphids in the greenhouse.—Eggplant and cucumber have been grown in pots during 1927 and 1928 in the greenhouse where the 1926 experiments were made. The fungus seems to have existed in the soil during all the time since our earlier experiments of 1926, for infestations of the aphids were readily stopped by its parasitizing effect. The question has been raised whether the fungus will survive in an environment where fungicides have to be systematically applied. No fungicides have been used in our greenhouse and no experiments have been planned with this point in mind, so that the question must await longer for its answer. It is only logical to expect that fungicides applied for the control of plant diseases will also hold the aphid parasite in check. Where frequent applications of sprays or fungicidal dusts are made the chances for the aphid fungus acting on its hosts will be lessened. However, it is hard to conceive that the pathogene will be eliminated from the soil unless treatments for the elimination of soil microorganisms are applied. Invasions of the aphids during the intervals between sprayings will probably be reached to some degree by the fungus.

SUMMARY

1. A fungus, *Acrostalagmus aphidum* Oud., parasitizes aphids in Porto Rico. It had been reported as *A. albus* Preuss.

2. The size of the spores in the various natural strata is more or less uniform.

3. The size of the spores appears to be larger for those produced on the natural strata than those developing on oatmeal agar cultures.

4. There seems to be a wider range of length and width of spores on our form than on the *A. aphidum* Oud. described in Saccardo's "Sylloge Fungorum".

5. Some of the conidia become one—to several—septate prior to germination.

6. Conidia or head-like structures are produced on germinating spores.

7. Some young conidia germinate while still attached to the head or to the branch tips.

8. Spores germinate rapidly in sugar solutions.

9. Spores rapidly lose their germinating power when dried.

10. Experiments indicate a possible stimulating effect of aphid juices on germination and development of spores. There are probably variations in the degree of that influence, according to species.

11. The fungus grows best at reactions of pH 6.93 to 7.93.

12. So far as is known, *Acrostalagmus aphidum* attacks the aphids on 17 species of the higher plants. Of these 8 had been reported previously and the remaining 9 are new additions. Among these are important crop plants.

13. The aphids which may be parasitized comprise five different genera of which two are here first reported. *Aphis pseudobrassicae* is first here reported parasitized by the fungus.

14. The fungus does not parasitize the corn aphid under natural conditions.

15. The fungus has also been reported on the eggplant lace-bug, *Corythaica monacha.*

16. *Acrostalagmus aphidum* can be employed successfully and cheaply in the control of the aphids of the eggplant. The method will probably be effective in field control of the aphids of other vegetables.

17. The pathogene lives in greenhouse soil. No experiment proof is at hand which would demonstrate whether the fungus is eliminated by the application of fungicides used for the control of plant diseases.

The writer wishes to express his deep gratitude to Miss Edith M. Patch, Entomologist of the Maine Agricultural Experiment Station who made the determination of some of the aphids and to Miss Vera K. Charles of the Bureau of Plant Industry, Washington, D. C., for valuable help in the specific determination of the fungus. He is also indebted to Dr. Mel. T. Cook for his suggestions and help in the preparation of the Manuscript.

LITERATURE CITED

1. **Johnston, John R.** Report of the pathologist. In Porto Rico Sugar Prod Ass'n Exp. Sta. Third Ann. Rept. 1913: 22–24.

2. ----------, ----. ----. The entomogenous fungi of Porto Rico. Porto Rico Bd. Com. Agr. Bul. 10: 9–33, pl. 1–9. 1915.
3. **Jones, Thos. H.** Aphides or plant-lice attacking sugar-cane in Porto Rico. Porto Rico Bd. Com. Agr. Bul. 11: 7–19, fig. 1–2. 1915.
4. **Stevenson, John A.** A check list of Porto Rican fungi and a host index. Porto Rico Dept. Agr. Jour. 2: 125–264. 1918.
5. **Wolcott, George N.** "Insectae Portoricensis." Porto Rico Dept. Agr. Jour. 7: 1–313. 1923.
6. **Zwaluwenburg, R. R. van.** Insects affecting coffee in Porto Rico. Jour. Ec. Ent. 10: 513–517. 1917.

EXPLANATION OF PLATES

PLATE XI

Fig. 1. Spores of *Acrostalagmus aphidum* germinating in the juice of the Cryptostegia aphid. Drawn at the end of 6½ hours.

Fig. 2. Spores germinating in the juice of the Cyperus aphid. Drawn at the end of 6½ hours.

Fig. 3. Spores germinating in water. Drawn at the end of 6½ hours.

Fig. 4. Spores germinating in water. Drawn at the end of 15 hours.

Fig. 5. Germinating spores producing a structure similar to the appresoria of the anthracnoses. The figure on the left shows the structure has germinated with the production of a secondary spore.

Fig. 6. Spores germinating while still attached to the sporophore.

Fig. 7. A bulb or blister-like affair produced by the fungus and which behaves in germination like a spore.

Fig. 8. Formation of heads or conglutination of spores. All stages.

Fig. 9. Single spores produced at the tips of fertile hyphae.

Fig. 10. The types of branching of the fertile hyphae of *A. aphidum*.

PLATE XII

Fig. 11. The undersurface of a leaf of *Abelmoschus esculentus* showing the parasitized aphids.

Fig. 12. Portions of the leaf of fig. 11, magnified about twenty times to show the colonies of *A. aphidum* on the dead bodies of aphids.


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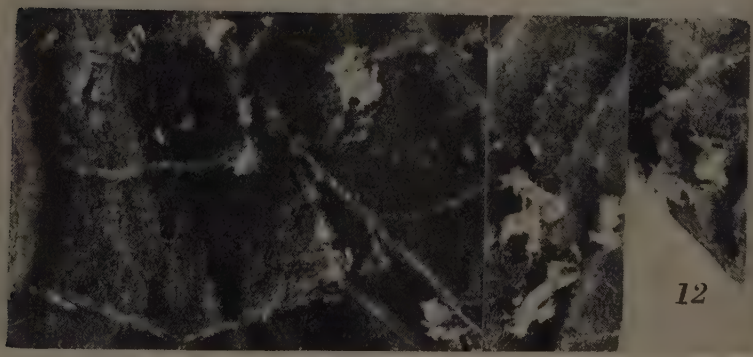

12

THE GUMMOSIS OF SUGAR CANE
(Second Paper)

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The first paper on this subject by the writer was published in "The Journal of the Department of Agriculture of Porto Rico", Vol. XII, No. 3, October 1928. At that time, it was our intention to continue the work for two or possibly three years longer, to make a second test of our established varieties and to test several newly introduced and promising varieties. But when our plots were harvested on March 14th and 15th, 1929, it was found that we did not have enough diseased seed cuttings for the establishment of new plots. Therefore, it was impossible to continue the work and became necessary to publish this brief resumé of the work to date. Those who are interested in this work should read the first paper.

The conditions for the growing of this third crop (2nd ratoon) have been very unfavorable. Following the cutting of the second crop (1st ratoon) in February 1928, we had dry weather. The weather conditions and the disease caused a growth that was very much less than the cane surrounding the plots. This reduced growth must be attributed primarily to the presence of the disease. This cane was in the path of the September 13th cyclone and was severely damaged. The cane was so poor as to be scarcely worth cutting if it had not been for our desire to make records of the amount of infection. The cane surrounding these experimental plots and separated from them by a wagon road only was up to the average.

A summarization of the amount of infection is as follows:

(1) Cristalina, which was planted from diseased seed in 1925 showed an average of less than one per cent infection. Eighteen rows of 45 stools each showed no infection. Twelve rows showed slight infection. The highest infection in any row was less than 4 per cent. The infection in 1927 was 85 per cent and in 1928 varied from less than 10 per cent in some rows to 50 per cent in other rows.

(2) PR–292, PR–492 and D–433 showed less than one per cent infection. They did not show any infection in 1928 but the number of living stools had been reduced in every case.

(3) Ba–11569 showed less than one per cent infection. In 1928 this variety showed 7.1 per cent infection and a loss of 3 stools out of 45.

(4) X–62 showed about two per cent infection. In 1928 this variety showed 7.7 per cent infection and a loss of 19 stools out of 45.

(5) B–3412 showed about two per cent infection. In 1928 this variety did not show any infection but there had been a loss of 5 stools out of 45.

(6) E.K.–28 showed five per cent infection. In 1928 this variety showed 50 per cent infection.

(7) D–504 showed about 17 per cent infection. In 1928 this variety showed an infection of 12.5 per cent and a loss of 8 out of 15 stools.

(8) Otaheiti showed but one living stool out of 45 stools planted in 1925. This stool had but two canes and both were infected.

(9) B–3405, B–6032, H–109, PR–219, PR–260, PR–328, PR–487, and PR–460 showed more or less infection in 1928 but no infection in 1929.

(10) The following varieties did not show any infection on either first (1928) or second (1929) ratoon: St. Kitts, Yellow Caledonia, Badila, GC–493, FC–214, SC–12(4), BH–10(12), D–109, D–117, D–1135, B–208, B–1753, B–1809, B–3696, B–6032, B–6308, PR–67, PR–202, PR–230, PR–329, PR–333, PR–358, PR–417 and PR–729.

(11) The following varieties did not show any infection on either the plant cane (1927) or the two ratoons (1928 and 1929): D–448, PR–318, POJ–228, POJ–234, POJ–826, POJ–979, M–36 and Uba.

In 1928 small plantings of several varieties were made and the results may be summarized as follows: BSF–1248, BH–10(12), Sealey seedling, Tuc–439, B–119, B–12079, PR–422, PR–430, PR–433, PR–502, PR–503, PR–545, PR–676, POJ–36, POJ–503, PR–1228, POJ–2725 and POJ–2776 which did not show any infection. D–357 showed one per cent infection and SC–12(4) showed five per cent.

The studies on this disease in Porto Rico and elsewhere present two very interesting questions. (1) Why does the disease appear suddenly in abundance? and (2) Why is the infection greater in plant than in ratoon cane?

Two and possibly more answers may be given to the first question. (*a*) The grower may unknowingly have planted infected seed. (*b*) The disease may have been present on a property in small infections for some time. Finally the grower may have used a large amount of seed from an infected area and the conditions may have been favorable for the development of the disease. The result is a large amount of disease in the crop.

The second question may possibly be explained as follows: A

large percentage of the shoots from an infected seed piece are likely to show infection which means a high percentage of infection in the crop as has been demonstrated by some of our experiments. The infection exists not only above the ground but also in the underground parts of the stems or rhizomes. In severely infected stools some of these underground parts are killed which results in a reduced tonnage in the crop. After the cutting of the first crop many of the new shoots are killed as shown in our experiments. The mortality among the small shoots is very high but shoots of five feet feet or more in height are sometimes killed. Shoots that are only slightly infected or that may escape infection entirely will survive but the tonnage of the ratoon crop is necessarily reduced in proportion to the death of the underground parts and new shoots. Since the surviving shoots are those that were healthy or only slightly infected the percentage of infection will be lower in the first ratoon than in the plant crop and lower in the second than in the first ratoon.

DISCUSSION

It appears from these studies that the planting of infected cane will give losses in first crop in proportion to the amount of infection in the seed, the relative resistance of the variety and the weather conditions during the growing season. Severely infected seed pieces may not germinate but very few such pieces will be used. Many of the new shoots from infected cuttings will die as a result of the disease which will reduce the crop. However, many slightly infected shoots will survive and the percentage of disease in the first crop or plant cane will be high.

In the production of the second crop (1st ratoon) many of the underground parts will die as a result of the disease. Many of the new shoots will die and others will be weak for lack of necessary plant food. The percentage of young shoots which die during the second year appears to be greater than during the first year. Therefore, the percentage of living infected shoots at cutting time is less than when the first crop is cut but the tonnage is also reduced as a result of the death of so many shoots.

Likewise the third crop (2nd ratoon), for the same reasons will show a still lower percentage of infection and a still lower tonnage. Of course both the percentage of infection and the amount of the tonnage may vary to some extent with the soil and weather conditions.

Under present conditions in Porto Rico, our two favorite canes, BH–10(12) and SC–12(4) can be grown with very little fear of losses

from gummosis, but the grower should never use seed cuttings from an infected field.

High producing susceptible varieties of sugar cane can be grown in territory where the disease is not present but in case the disease appears in these localities the growers should replant the infected fields with highly resistant varieties. The POJ canes which we have tested in Porto Rico appear to be immune to the disease.

The abandoning of the old favorites such as Cristalina, Rayada, Otaheiti and Yellow Caledonia, the increased planting of BH–10(12), SC-12(4), Uba and the POJs, leads the writer to believe that the gummosis disease is a diminishing factor in Porto Rico. However, any disease is a menace to the crop on which it exists, because a change in conditions may enable it to become a dangerous factor. So long as this disease exists on the island, it will be a dangerous factor in the development of or introduction of a new desirable but susceptible variety.

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